Acute abdominal pain in childhood and adolescence: assessing the impact of sonography on diagnosis and treatment

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Abstract

Purpose To assess the impact of ultrasonography on defining the diagnostic and therapeutic pathways for pediatric patients admitted to the emergency department for acute abdominal pain.

Methods We performed a retrospective study of all patients aged <16 years with acute abdominal pain who underwent ultrasound examination at our Diagnostic Imaging Department from October 2010 to March 2012. We investigated for each patient the pathway following ultrasound examination and definitive diagnosis. The impact of ultrasonography was defined based on the frequency with which the information resulting from this examination confirmed or denied the diagnostic suspicion made by the emergency physician on the basis of clinical and laboratory findings.

Results In 497/729 patients (69 %), ultrasound examination did not determine variations in the diagnostic and therapeutic pathways, either because it confirmed the outcome of clinical examination and laboratory tests, or because, even addressing in the opposite direction to

these, the emergency physician did not consider its result because of being particularly alarmed or sufficiently reassured by clinical examination and laboratory tests. In the remaining 232/729 cases (31 %), ultrasound examination determined an increase or a reduction of the provided care and attention (subsequently proved justified in the vast majority of cases) in spite of what was initially assessed based on clinical examination and laboratory tests.

Conclusions The results of our retrospective study demonstrated that ultrasonography was a valuable tool in the management of pediatric patients with acute abdominal pain together with clinical examination and laboratory tests.

Keywords Appendicitis · Ultrasonography · Acute abdominal pain · Childhood · Adolescence

Riassunto

Obiettivo definire l'impatto dell'ecografia nella scelta dei percorsi diagnostici e terapeutici per i pazienti pediatrici giunti al Pronto Soccorso con dolore addominale acuto.

Metodi abbiamo eseguito uno studio retrospettivo su tutti i pazienti di età inferiore a 16 anni con dolore addominale acuto valutati con esame ecografico presso il nostro Dipartimento di Radiologia nel periodo compreso tra l'Ottobre del 2010 ed il Marzo del 2012. Abbiamo valutato per ciascun paziente il percorso diagnostico e terapeutico successivo all'esecuzione dell'esame ecografico e ricercato la diagnosi definitiva. L'impatto dell'ecografia è stato definito in base alla frequenza con la quale le informazioni risultanti da questo esame confermassero o smentissero il sospetto diagnostico formulato dal medico del pronto Soccorso sulla base dei risultati dell'esame clinico e dei test laboratoristici.

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Risultati in 497/729 pazienti (69 %) l'esame ecografico non ha determinato variazioni dei percorsi diagnostici e terapeutici, o perchè ha confermato il risultato degli esami clinici e laboratoristici, o perchè, pur indirizzando in senso contrario rispetto ad essi, il medico di Pronto Soccorso ha deciso di non tenere in considerazione le informazioni da esso derivanti perchè particolarmente allarmato o sufficientemente rassicurato dall'esame clinico o dai test di laboratorio. Nei restanti 232/729 casi (31 %) l'esame ecografico ha determinato un incremento o una riduzione delle cure e dell'attenzione fornite (variazioni successivamente dimostrate giustificate nella grande maggioranza dei casi) rispetto a quanto inizialmente definito sulla base dell'esame clinico e dei test di laboratorio.

Conclusioni il risultato del nostro studio retrospettivo ha dimostrato che l'ecografia è uno strumento utile nella gestione dei pazienti pediatrici affetti da dolore addominale acuto unitamente alla valutazione clinico-laboratoristica.

Introduction

Acute abdominal pain represents, along with trauma, the leading cause of access to an emergency department (ED) in childhood and adolescence [3, 5, 7]; in our department, there are approximately 800 admissions per year for this issue.

Faced with a case of acute abdominal pain in a child, an emergency physician is primarily asked to identify as quickly as possible the cause of the pain, so differentiating cases to be monitored clinically by those to be treated surgically.

This task is not easy in all cases, even more considering that frequently, especially in the first years of life, children are unable to describe their symptoms and refuse to cooperate during the execution of clinical examination and diagnostic tests, so limiting their information content [5]. The intrinsic complexity of certain diseases causing acute abdominal pain, characterized by very little specific clinical, laboratory and radiological findings, represents another important limitation to the formulation of a correct and timely diagnosis [4, 5, 7, 11].

There are several causes of acute abdominal pain in childhood and adolescence, with the vast majority, not all (e.g., pneumonia or diabetic ketoacidosis), directly related to diseases of the abdominal viscera. The most frequent, acute appendicitis, also represents one of the most severe diseases and is often frequently associated with a complex prognosis [1, 2, 6, 12, 17], primarily because of the considerable aspecificity of clinical signs and laboratory abnormalities related to it, often complicating the formulation of a certain diagnosis (not infrequently the diagnosis is performed only at the operating table). Moreover,

persistent and intense pain complained by young patients for a variety of causes that may mimic acute appendicitis can lead to unnecessary appendicectomies [12].

Imaging has a key role in limiting inadequate interventions and, more generally, setting the most appropriate therapeutic approach. Imaging, in the management of acute abdominal pain, is mainly based on the triad: abdominal ultrasound, chest X-ray and abdominal X-ray [12, 18–20]. In particular, abdomen ultrasonography (US), being fast, cheap, widely available and, first of all, unencumbered by the limits of the use of ionizing radiation (the latter a not negligible element in children), has been invested with great responsibility since its introduction into the field of emergency [20].

Several studies in the last decades have proposed ultrasonography as one of the main diagnostic tools in children with acute abdominal pain [1–4, 11, 12, 14, 23, 27–29]. To date, however, the impact of US on defining the diagnostic and therapeutic pathways for these patients remains indeterminate.

The aim of our retrospective study was to assess these parameters; in particular, we focused on the accuracy of US in diagnosing appendicitis and also reported the most common ecographic signs associated with this condition in our series.

Materials and methods

Study protocol

Our study was performed in the ED of a major city hospital, the second largest in the region of Campania (one of the most densely populated Italian regions, with ~7 million inhabitants) in the number of admissions. In our Department of Diagnostic Imaging, a dedicated service for emergencies with at least two radiologists is available throughout the entire 24-h period.

We performed a retrospective study of all patients aged <16 years with acute abdominal pain who underwent US of the abdomen at our department from October 2010 to March 2012. The total number of patients whose examinations were retrospectively evaluated was 1,150 (641 females, 509 males, aged between 2 and 16 years, with a mean age of 7.7 years).

In all cases, US had been required by a physician experienced in emergency medicine on the basis of medical history (e.g., duration and type of pain, associated symptoms), symptoms reported by the patients' parents or by the patients themselves and laboratory tests (e.g., increased WBC). We excluded from our study patients initially evaluated by US in other hospitals and then transferred to our ED.

This study was approved by the ethics committee of our hospital. Because the study protocol and the aim of our study did not influence in any way the diagnostic and treatment approaches, we felt it unnecessary to obtain informed consent from the parents of the young patients.

In all cases where radiological examinations are urgently required at the Diagnostic Imaging Department of our hospital, it is necessary that the requesting ED physician fill in a default model with the following information: demographic data, type and duration of symptoms, results of physical examination and any abnormal laboratory test. Based on these factors, finally, the requesting physician is asked to make a presumptive diagnosis on the same module.

In cases where no precise diagnostic suspicions and only inconsistent and aspecific laboratory test abnormalities are obtained, a common occurrence in emergency medicine, the requesting physician classifies the pain as “abdominal colic of undetermined origin.”

For all patients included in our study, we investigated retrospectively, in collaboration with the physicians of the ED, the pathway following US (discharge from the ED after a mild therapy, admission to a division of short monitoring, admission to a long-term care division, admission to an intensive care unit, urgent laparotomy or laparoscopy) and the definitive diagnosis obtained from discharge notes, medical records or surgical registers.

All examinations were performed by radiologists trained in pediatric US, using the same ultrasound scanner (MyLab 50, Esaote, Genova, Italia), equipped with a convex and a linear multifrequency probe. In all cases a graded compression on the right lower abdominal quadrant was performed.

Data analysis

The impact of US on diagnostic and therapeutic pathways for patients included in our study was defined based on the frequency with which the information resulting from this examination confirmed or denied the diagnostic suspicion made by the physician of the ED on the basis of clinical and laboratory findings.

The real diagnostic efficacy of US performed in our department for emergency patients, then, was defined by comparing the diagnostic suspicion made by the radiologist with the final diagnosis obtained from the notes of discharge from medical divisions or from surgical registers. The decisive factors in defining this parameter, in particular, were the number of interventions classified as appropriate and inappropriate (so-called “undertreatment” and “overtreatment”) made on the basis of the suspected diagnosis performed at ultrasonography.

Results

During the 18 months considered in our study, we performed US of the abdomen and pelvis on a total of 1,150 pediatric patients for the evaluation of acute abdominal pain.

The examined population consisted of 641 females and 509 males, aged between 2 and 16 years, with an average age of 7.7 years.

From this series we eliminated 421 patients (290 females and 131 males) because we did not have adequate information about the final diagnosis (in most cases patients had been discharged from the ED after mild therapy with a definitive diagnosis of “abdominal pain of undetermined origin” or a voluntary resignation had been previously signed by both parents despite the contrary opinion of the emergency doctor).

Thus, the final sample consisted of 729 patients, 351 females and 378 males, with a mean age of 8.1 years and an age range between 2 and 16 years.

Discharge from the ED

Of these 729 patients, about one-third of the cases (213, 29 %) were discharged from the ED after mild therapy with a diagnosis of “acute abdominal pain of undetermined origin” following a period of observation varying from 2 to 6 h, on the basis of the negativity of laboratory tests and US.

More than half of these patients (144, 67 %) had come to our attention with a diagnosis of “abdominal pain of undetermined origin” made by the emergency physician in the ED; in these cases, US did not carry a substantive change in diagnostic and therapeutic pathways, confirming the initial suspicion of the ED physician. We classified this group as CL (clinical) – US (ultrasound) –.

In the remaining 69 patients, however, clinical examination together with the abnormalities of hematochemical tests induced to make a presumptive diagnosis of acute appendicitis in 36 cases, urinary tract infection in 8 cases, gastroenteritis in 6 cases, mesenteric adenitis in 6 cases, small bowel obstruction in 5 cases, incarcerated hernia in 4 cases, ovarian torsion in 2 cases and intussusception in the other 2 cases. US, not leading to the identification of defined pathological conditions, induced the physician of the ED to discharge the patient, in spite of the initial orientation CL + US –.

These 213 cases, of which we do not know the story after discharge from ED, cannot be taken into account as defining the real effectiveness of US; however, we will reconsider them in the final assessment of the impact of US on determining the diagnostic and therapeutic pathways in our series.

Admission to divisions of short-term medical observation and long-term care

Two hundred and sixty-eight of the 729 patients (37 %), after admission to the ED, were held in a division of short-term (ranging, according the guidelines of the hospital, between 6 and 48 h) medical observation or in the division of long-term care based on the results of clinical, laboratory and sonographic examinations. 170 of these patients came to our attention with positive clinical and laboratory tests: of these 170, 106 patients (62 %) had pathologic findings at US (CL + US +); in the remaining 64 patients (38 %) US was negative (CL + US –).

In the majority of the 106 CL + US + patients (73 patients, 69 %), it was possible to identify a defined cause of abdominal pain from the discharge records of the ED or the registers from short-term observation or long-term care divisions (urolithiasis, infection of dilatation of the urinary tract, $n = 18$; small bowel obstruction, $n = 15$; Crohn's disease/infectious ileocolitis, $n = 14$; incarcerated hernia, $n = 8$, pancreatitis, $n = 7$; salpingitis, $n = 5$, mesenteric adenitis, $n = 4$; splenomegaly in sickle cell anemia, $n = 1$; lymphoma, $n = 1$).

In about one-third of the 106 patients CL + US + (33 patients, 31 %), instead, after further laboratory and instrumental tests, discharge from the divisions of short-term medical observation and long-term care happened in an interval comprising between 3 and 7 days with a definitive diagnosis of “abdominal pain of undetermined origin”.

With regard to the 64 CL + US – patients, instead, in 44 cases (68 %), despite the negativity of US, a definitive diagnosis was obtained (urinary tract infection, $n = 10$; small bowel obstruction, $n = 6$; pneumonia, $n = 5$; dysmenorrhea, $n = 3$; Crohn's disease/infectious ileocolitis, $n = 3$; primitive peritonitis, $n = 3$; typhlitis, $n = 3$; endometriosis, $n = 3$; drug intoxication, $n = 3$; food intolerance, $n = 1$; acute adrenal insufficiency, $n = 1$; hematocolpos, $n = 1$; diabetic ketoacidosis, $n = 1$; pelvic inflammatory disease with positive bacterial culture, $n = 1$), with discharge from short-term observation or long-term care divisions within an interval ranging between 3 and 12 days.

In the remaining 20 patients, CL + US – (32 %), instead, the negativity of US was associated with a dismissal from short-term observation or long-term care divisions within an interval ranging between 3 and 6 days with a diagnosis of “abdominal pain of undetermined origin”.

In 98 of the 268 cases (36 %), hospitalization was decided for positivity of US, even without univocal clinical and laboratory findings.

Fig. 1 A 15-year-old girl (CL+) complained of intense pain in the periumbilical region and in the right lower quadrant. US **a** showed a thickened-wall structure containing gas and hyperechoic material (arrow) with rear attenuation of the ultrasound beam (asterisk). The sonographer, uncertain between Meckel's diverticulitis and appendicitis, decided to perform a CT scan. CT **b** showed an appendicolith (arrow) within a dilated appendix, with thickened, hyperemic walls. Stranding of the surrounding fat is well appreciable

Of these 98 patients, in 70 cases (71 %) a definitive diagnosis was reached (appendicitis, $n = 26$; intussusception, $n = 12$; small bowel obstruction, $n = 9$; typhlitis, $n = 8$; urinary tract obstruction, $n = 6$; incarcerated hernia, $n = 4$; volvulus, $n = 3$; mesenteric adenitis, $n = 2$), with need for diagnostic deepening with CT in 12 (Fig. 1a, b) cases and surgery in 10 cases.

Admission to the intensive care unit

In 10 of the total 729 patients (1 %), an immediate transfer to the division of intensive care was performed.

Of these ten patients, in eight cases clinical and laboratory findings were positive (CL + US +); in two cases, instead, ultrasound examination did not provide positive findings (CL + US –).

In all these ten cases, the transfer to the intensive care unit proved to be necessary (typhlitis, $n = 4$; appendicitis, $n = 3$; volvulus, $n = 3$).

Surgery

Considering, finally, the 238 patients surgically treated few hours after admission to the ED (explorative or operative laparotomy or laparoscopy), in about half of the cases (122 patients, 51 %) clinical and laboratory findings as well as US definitely indicated surgery (appendicitis, $n = 58$; volvulus, $n = 12$; intussusception, $n = 15$; urinary calculi, $n = 13$; small bowel obstruction, $n = 9$; Crohn's disease/infectious ileocolitis, $n = 5$; cholecystitis, $n = 4$; mesenteric infarction, $n = 5$), in 51 patients (21 %) US did not reveal significant elements despite the positivity of clinical and laboratory findings (intussusception, $n = 15$; volvulus, $n = 13$; incarcerated hernia, $n = 7$; salpingitis, $n = 7$; omental infarction, $n = 6$; Meckel's diverticulitis, $n = 2$) and in 65 patients (28 %), the most important result for us, US indicated surgery (in 11 cases after CT evaluation) despite non-specificity of clinical examination and laboratory tests (volvulus, $n = 20$; intussusception, $n = 18$; ischemic colitis, $n = 12$; ovarian torsion, $n = 7$; urinary calculi, $n = 3$; cholecystitis and cholelithiasis, $n = 3$; Crohn's disease/infectious ileocolitis, $n = 2$).

In 212 cases, surgery proved necessary, adequate and resolute for painful symptoms.

26 interventions, finally, subsequently proved unnecessary: in all cases (all 26 suspected appendicitis), US had not identified abnormal findings.

Overall data evaluation

In 497 patients (69 %), US required by the ED physician did not determine variations in the diagnostic and therapeutic pathways, either because it confirmed the outcome of clinical examination and laboratory tests, or because, even addressing in the opposite direction to these, the emergency physician did not consider its result because of being particularly alarmed or sufficiently reassured by clinical examination and laboratory tests.

In the remaining 232 cases (31 %), US determined an increase or a reduction of the provided care and attention in spite of what was initially assessed based on clinical examination and laboratory tests.

Of the 232 patients in whom US changed the diagnostic and therapeutic pathways, in 69 cases (30 %) it reduced the level of attention and care given to patients (discharge from

the ED), and in 163 cases (70 %) it indicated an increase in attention and care (hospitalization or surgery).

We could not define the real effectiveness of US in the first 69 cases, since patients were discharged from the ED. Of the remaining 163 patients, however, in 135 cases (83 %) the increase of care and attention given proved justified with respect to the final diagnosis and in the remaining 17 % of cases (28 patients) unjustified (all cases were discharged from the ED with a final diagnosis of "abdominal pain of undetermined origin" after further investigation during hospitalization in short-term observation or long-term care divisions).

With regard to the 186 cases where US was negative in spite of the positivity of clinical and laboratory outcomes, except 69 cases (CL + US –) discharged after access to the ED and the first laboratory and instrumental tests, only in 46 cases (39 % of the remaining 117 cases) it proved to be actually ineffective; in the remaining 61 % of cases, however, hospitalization (20 patients) and surgery (51 patients) proved unnecessary or inconclusive.

Discussion

Two were the most significant results of our study: the appropriateness of the increase of care and attention in the vast majority of cases as indicated by US (83 %) and the inappropriateness of care and attention in about a third of cases as indicated by US in the other direction (61 %), in both cases contradicting the opinion of the emergency physician.

In our series, as in the vast majority of studies in the literature [1, 3–5, 9, 11, 27, 28], the most frequent diagnosis was appendicitis (87 patients, 16 % of the total 516 cases, not considering the 213 discharged after the first assessments from the ED). Apart from the case of the 36 patients admitted to the ED with a suspicion of acute appendicitis and discharged a few hours after based on the results of US, cases that we cannot include, as already written, in the overall analysis of the data, US proved to be essential in defining diagnostic and therapeutic pathways in 26 patients with unclear clinical and laboratory findings (all hospitalized in short-term or long-term observation units and then proved to be "mild" appendicitis), in 3 patients arrived at the ED in poor general conditions and admitted to the intensive care unit (in these cases, also confirmed by CT examination, findings from clinical examination, laboratory test and US proved to be concordant), in 58 patients, surgically treated on the basis of positive clinical and laboratory findings and US (in all cases acute appendicitis was confirmed at the operating table), and in 26 cases in which US had oriented, contrary to the results of clinical examination and laboratory tests oriented, for

Fig. 2 An 11-year-old boy (CL+) with intense pain in the right lower quadrant. US confirmed the suspicion of acute appendicitis by the identification of the typical “target sign”, created by the succession of three layers: an external hypoechoic ring represented by the muscularis mucosa, an intermediate echoic layer represented by the mucosa and the submucosa and an internal hypo-anechoic layer represented by intra-appendicular fluid

medical therapy. In all these 26 patients surgery proved inappropriate. A quick and effective diagnosis is essential in pediatric patients with acute appendicitis: the incomplete development of the omentum, in fact, involves the tendency of the infection to spread immediately to the peritoneum, with rates of perforation reported in the literature much higher than in the adult population (varying between 30 and 65 %) [10, 12].

US of the appendicular region in children is usually easy, since they have a lower component of fat in the abdominal wall compared with adults [10, 24]. Graded compression of the appendix is an useful tool in determining the presence of inflammation: an inflamed appendix is usually aperistaltic, difficult to compress, larger than 6 mm in diameter (Fig. 2). It is important for the ultrasonographer to visualize the entire appendix to avoid a false-negative reading because sometimes only the distal tip of the appendix is inflamed. The mucosal lining might be intact or poorly defined, and a fecalith might or might not be present. Periappendiceal fluid collection might indicate an early perforation but might result simply from inflammation [12, 25]. Experienced ultrasonographers can achieve sensitivities of 85–90 % and specificities of 95–100 % in acute appendicitis [3, 4, 8, 9, 11, 13, 26, 27], but studies have not shown an improvement in outcome measures such as a decrease in negative laparotomies or time to the operating room [15, 16, 21].

Unfortunately, sonographic diagnosis of appendicitis is not always so easy in the childhood: there are in fact limiting factors related both to the patient (lack of

cooperation during the examination, position of the appendix—e.g., retrocecal appendix, interposition of gas-filled intestinal loops) and to the operator (mainly lack of experience and/or capacity) [22].

Limitations of our study were, in addition to the inclusion in the series of patients discharged with negative sonographic examination from the ED a few hours after admission, the short follow-up for all patients included in our series (at most 6 weeks), the lack of objective criteria for the request of ultrasound examination in patients admitted to the ED (it is unavoidable that some physicians require a greater number of tests than others and that there may be different decision paths notwithstanding the same clinical, laboratory and ultrasonographic situation) and, last but not less important, the fact that US is an “operator-dependent” examination and that in evaluating the same patient two sonographers can obtain different information, thus formulating different diagnoses.

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Conflict of interest A. Russo, S. Cappabianca, F. Iaselli, A. Regnelli, A. D’Andrea, G. Mazzei, C. Martiniello, R. Grassi and A. Rotondo declare that they have no conflict of interest.

Informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). All patients provided written informed consent to enrollment in the study and to the inclusion in this article of information that could potentially lead to their identification.

Human and animal studies The study was conducted in accordance with all institutional and national guidelines for the care and use of laboratory animals.

References

1. Babcock DS (2002) Sonography of the acute abdomen in the pediatric patient. *J Ultrasound Med* 21:887–899
2. Baldisserotto M, Marchiori E (2000) Accuracy of noncompressive sonography of children with appendicitis according to the potential positions of the appendix. *Am J Roentgenol* 175(5):1387–1392
3. Barr LL (1994) Sonography in the infant with acute abdominal symptoms. *Semin Ultrasound CT MR* 15(4):275–289
4. Carrico CW, Fenton LZ, Taylor GA et al (1999) Impact of sonography on the diagnosis and treatment of acute lower abdominal pain in children and young adults. *Am J Roentgenol* 172(2):513–516
5. Carty HM (2002) Paediatric emergencies: non-traumatic abdominal emergencies. *Eur Radiol* 12(12):2835–2848 Epub 2002 Jul 27
6. Crady SK, Jones JS, Wyn T et al (1993) Clinical validity of ultrasound in children with suspected appendicitis. *Ann Emerg Med* 22(7):1125–1129

7. D'Agostino J (2002) Common abdominal emergencies in children. *Emerg Med Clin North Am* 20(1):139–153
8. Gatta G, Parlato V, Di Grezia G et al (2010) Ultrasound-guided aspiration and ethanol sclerotherapy for treating endometrial cysts. *Radiol Med* 115(8):1330–1339
9. Hahn HB, Hoepner FU, Kalle T et al (1998) Sonography of acute appendicitis in children: 7 years experience. *Pediatr Radiol* 28(3):147–151
10. Heller MT, Hattoum A (2012) Imaging of acute right lower quadrant abdominal pain: differential diagnoses beyond appendicitis. *Emerg Radiol* 19(1):61–73
11. Hryhorczuk AL, Mannix RC, Taylor GA (2012) Pediatric abdominal pain: use of imaging in the emergency department in the United States from 1999 to 2007. *Radiology* 263(3):778–785 Epub 2012 Apr 24
12. Hung MH, Lin LH, Chen DF (2012) Clinical manifestations in children with ruptured appendicitis. *Pediatr Emerg Care* 28(5):433–435
13. Iacobellis F, Beritto D, Somma F, Cavaliere C, Corona M, Cozzolino S (2012) Magnetic resonance imaging: a new tool for diagnosis of acute ischemic colitis? *World J Gastroenterol* 18(13):1496–1501. doi:[10.3748/wjg.v18.i13.1496](https://doi.org/10.3748/wjg.v18.i13.1496)
14. Klein MD (2007) Clinical approach to a child with abdominal pain who might have appendicitis. *Pediatr Radiol* 37(1):11–14 Epub 2006 Oct 17
15. Kwok MY, Kim MK, Gorelick MH (2004) Evidence-based approach to the diagnosis of appendicitis in children. *Pediatr Emerg Care* 20(10):690–698
16. Leschka S, Alkadhi H, Wildermuth S et al (2005) Multi-detector computed tomography of acute abdomen. *Eur Radiol* 15(12):2435–2447
17. Lessin MS, Chan M, Catallozzi M et al (1999) Selective use of ultrasonography for acute appendicitis in children. *Am J Surg* 177(3):193–196
18. Mandato Y, Reginelli A, Galasso R et al (2012) Errors in the radiological evaluation of the alimentary tract: part I. *Semin Ultrasound CT MR* 33(4):300–307
19. Marin JR, Alpern ER (2011) Abdominal pain in children. *Emerg Med Clin North Am* 29(2):401–428
20. Mason JD (1996) The evaluation of acute abdominal pain in children. *Emerg Med Clin North Am* 14(3):629–643
21. McNamara R, Dean AJ (2011) Approach to acute abdominal pain. *Emerg Med Clin North Am* 29(2):159–173
22. Orr RK, Porter D, Hartman D (1995) Ultrasonography to evaluate adults for appendicitis: decision making based on meta-analysis and probabilistic reasoning. *Acad Emerg Med* 2(7):644–650
23. Pinto A, Romano S, Del Vecchio W et al (2000) Personal experience in 71 consecutive patients with acute cholecystitis. *Radiol Med* 99(1–2):62–67 (Italian)
24. Prashanth GP, Angadi BH, Joshi SN et al (2012) Unusual cause of abdominal pain in pediatric emergency medicine. *Pediatr Emerg Care* 28(6):560–561
25. Quillin SP, Siegel MJ (1995) Diagnosis of appendiceal abscess in children with acute appendicitis: value of color Doppler sonography. *Am J Roentgenol* 164(5):1251–1254
26. Ramachandran P, Sivit CJ, Newman KD et al (1996) Ultrasonography as an adjunct in the diagnosis of acute appendicitis: a 4-year experience. *J Pediatr Surg* 31(1):164–167
27. Rice HE, Arbesman M, Martin DJ et al (1999) Does early ultrasonography affect management of pediatric appendicitis? A prospective analysis. *Pediatr Surg J* 34(5):754–758
28. Scammell S, Lansdale N, Sprigg A et al (2011) Ultrasonography aids decision-making in children with abdominal pain. *Ann R Coll Surg Engl* 93(5):405–409
29. Scholer SJ, Pituch K, Orr DP et al (1996) Clinical outcomes of children with acute abdominal pain. *Pediatrics* 98(4 Pt 1):680–685